The DEEP2 Galaxy Redshift Survey: Groups and Clusters of Galaxies at z~1

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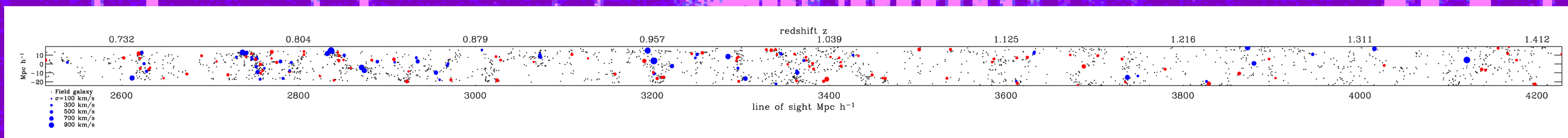


Figure 1: Groups in the most uniformly observed DEEP2 field, projected through one transverse dimension (about 35 Mpc/h at z=1). Colored circles indicate the locations of groups, with diameters proportional to group velocity dispersion. Black symbols are isolated galaxies. Groups have been identified using the Voronoi-Delaunay group-finding algorithm.

What is DEEP2?

In Summer 2002, the DEEP2 Redshift Survey began observations at the Keck Observatory. Today we are halfway to our goal of obtaining spectra of ~50,000 galaxies at z~1, to a magnitude limit of R_{AB}>24.1, with higher velocity resolution than any comparable sample of local galaxies. This survey is made possible by DEIMOS, a new multi-object spectrograph at Keck.

Scientific Goals of DEEP2:

1) Characterize the properties of galaxies at z~1 and their evolution with redshift

2) Study the clustering statistics of high-redshift galaxies, illuminating the evolution of clustering bias with redshift.

3) Measure the small-scale "thermal" motions of galaxies at z~1, providing a measure of Ω_M.

4) Measure cosmological parameters using the apparent abundances of galaxies and clusters at high redshift.

Identifying groups and clusters in the DEEP2 sample is crucial to attaining these goals.

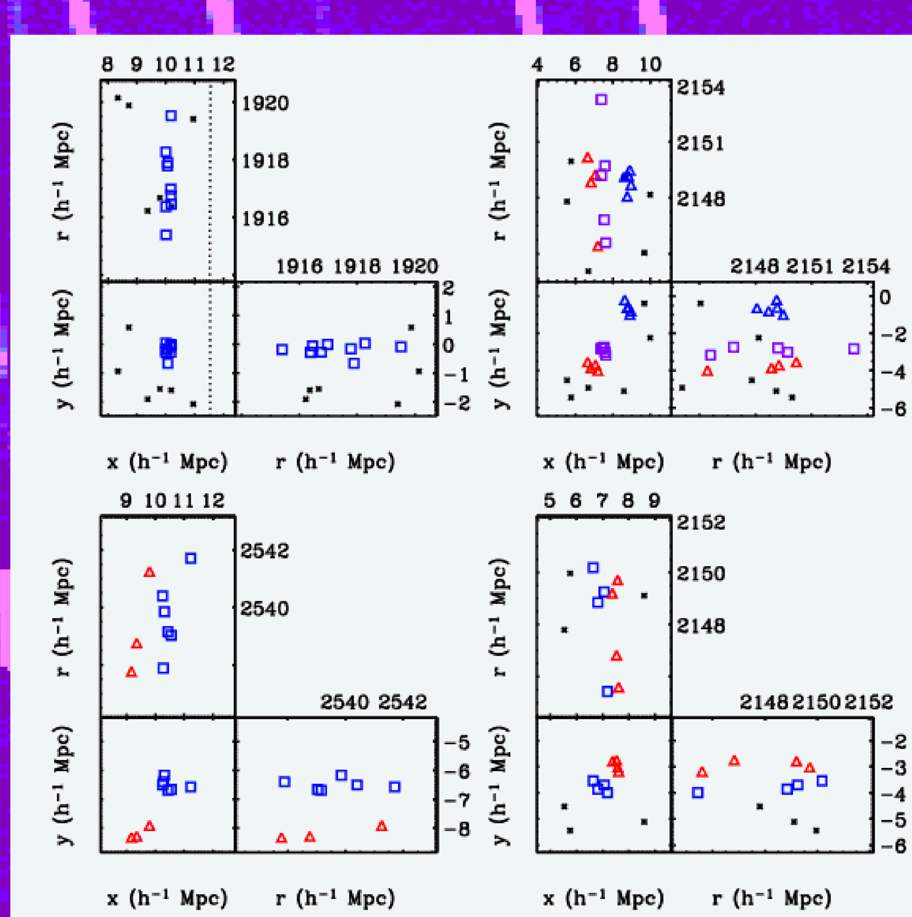


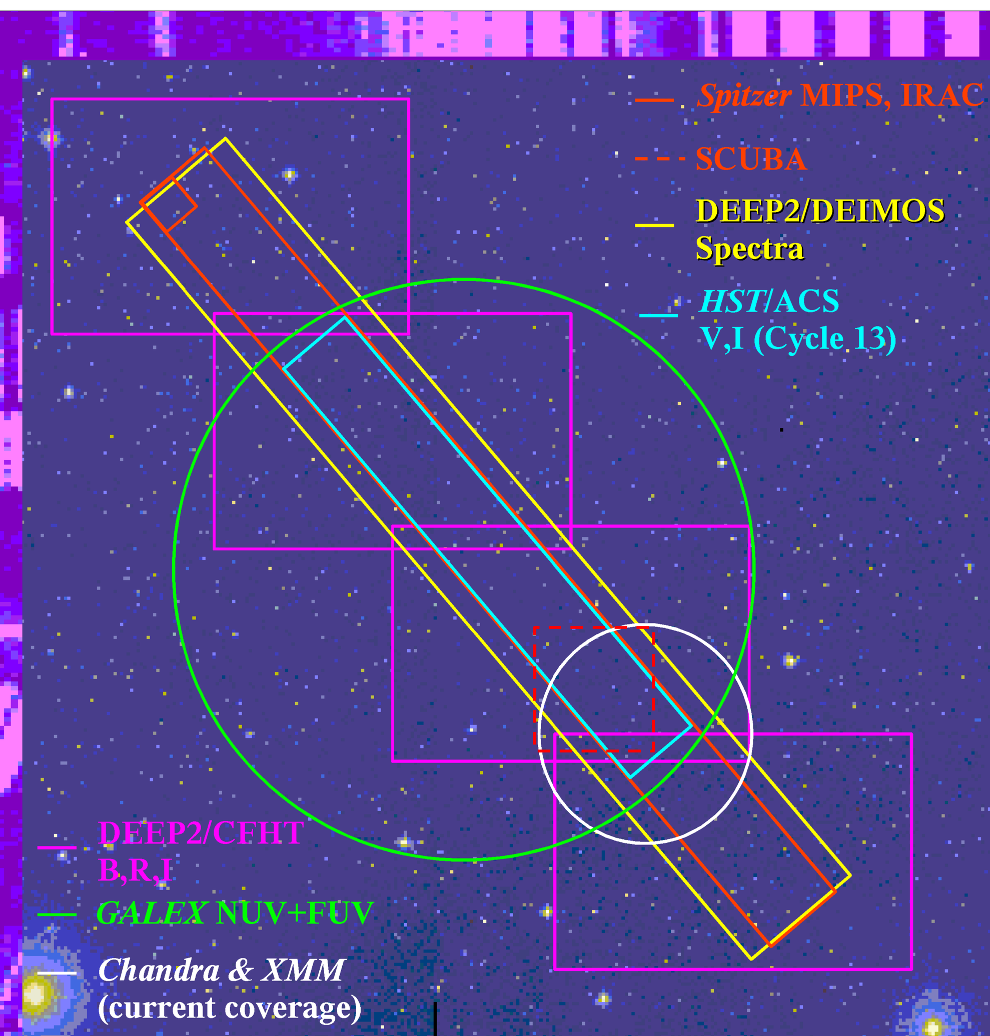
Figure 2: Close-up view of four DEEP2 groups. Each group's galaxies are indicated by colored squares, and nearby groups are shown by colored triangles. Isolated galaxies are indicated by black dots. Each group is shown in three different projections.

Group Finding at z~1

Identifying groups and clusters of galaxies in DEEP2 is difficult for several reasons.

- Redshift-space distortions smear out clustering.
- Clusters of galaxies are smaller and rarer at z~1 than locally.
- The realities of multi-object spectroscopy mean that we undersample dense regions.
- Our R-band (rest-frame U-band) selection biases us against red galaxies, which are common in clusters.

Therefore, we must have a method that reliably reconstructs groups when we only have the redshifts of a few members. We use the Voronoi-Delaunay Method (VDM) of Marinoni et al 2002(*ApJ*, 580, 122).



The Extended Groth Strip

One of the DEEP2 Fields is the Extended Groth Strip (RA 14h 17m, dec 52d 30m), which has become a target for a variety of ground- and space-based observations within a two-degree square field. In addition to the observations shown above, a proposal for wider *Chandra* imaging has been submitted, and deep Sunyaev-Zel'dovich maps are planned. This pan-spectral coverage will allow detailed studies of groups and clusters to z>1, while making possible a wide array of studies of galaxies, AGN, etc. as well.

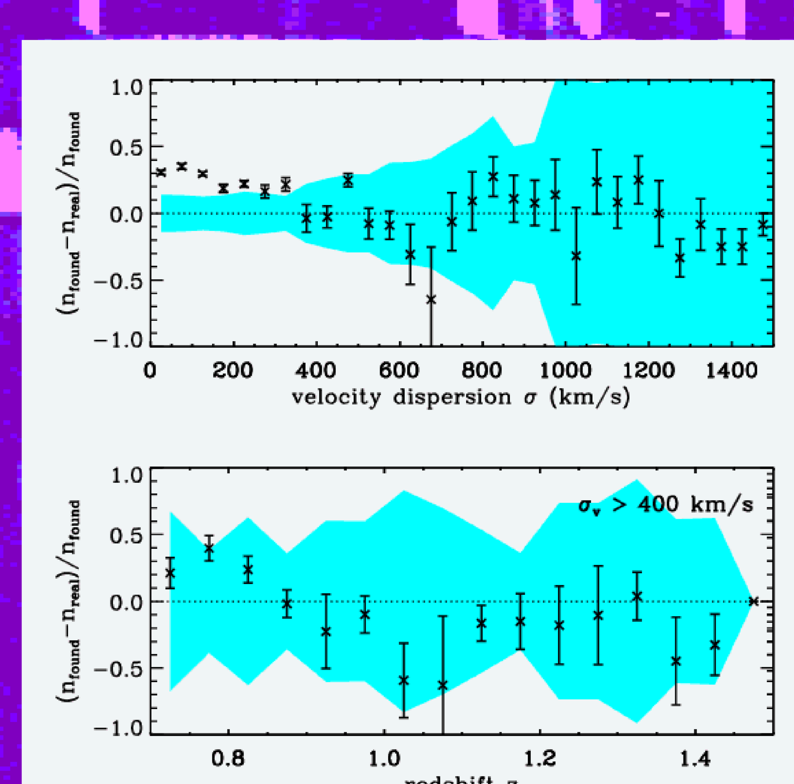
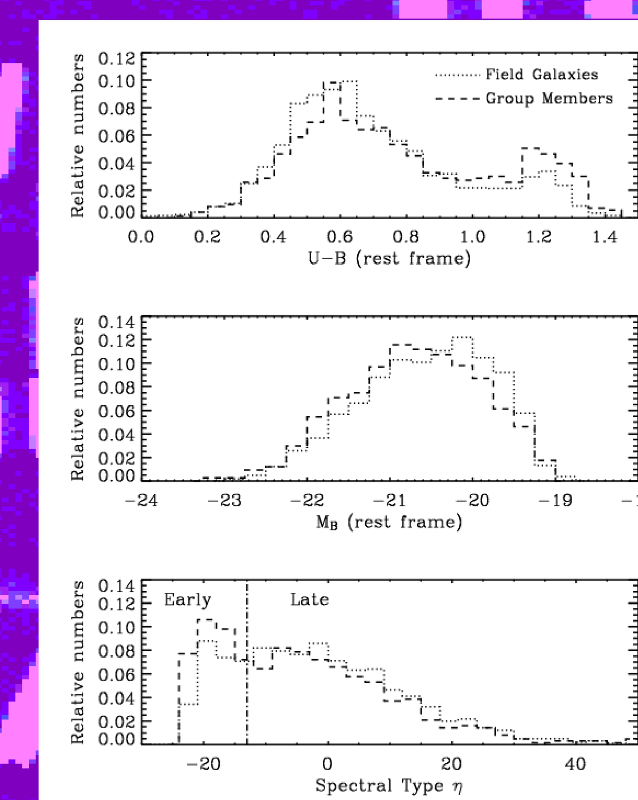


Figure 3: Errors in reconstructed n(σ) and n(z) distributions for groups found in DEEP2 mock catalogs. Shown are the mean fractional errors for twelve mock catalogs; error bars indicate the standard deviation of the mean. Shaded regions indicate cosmic variance. Errors are largely consistent with zero for σ>400 km/s, with systematics that are smaller than the cosmic variance.

Gauging Success

To measure cosmological parameters, we must reconstruct accurately the distribution n(σ,z) of groups and clusters in velocity dispersion and redshift. Tests on mock DEEP2 catalogs indicate that this is possible for σ>400 km/s (Figure 3). Figure 5 shows that the measured n(σ) distribution is consistent with the expectation from mocks.

Figure 4: Environmental dependence of galaxy properties. Shown are histograms of galaxy colors, magnitudes and spectral types (as derived in Madgwick et al. 2003 [ApJ, **599**, 997]). The galaxy sample is drawn from the redshift range 0.75<z<0.9. Clear differences are evident between group and field populations for all three properties.

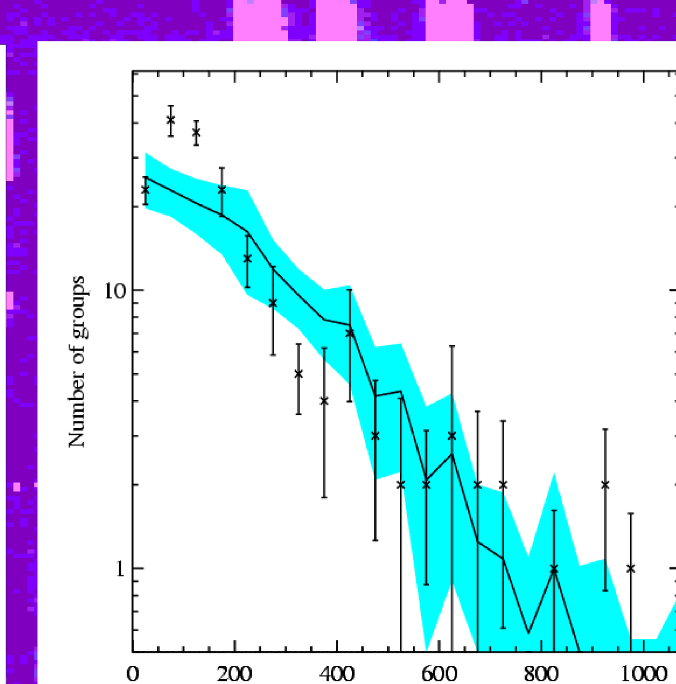


Science with Groups

Galaxy Formation: The properties of nearby galaxies are strongly correlated with galaxy environment. By comparing galaxies in different environments in DEEP2 (Figure 4), we may study this correlation at high redshift and gain insight into its causes. Imaging with the *Hubble* and *Spitzer* space telescopes will contribute important new information to such studies.

Cosmology: Clusters are rare events whose abundance is dependent on the large-scale structure growth factor *D(z),* which depends on the cosmological parameters Ω_m, Ω_Λ and w. Thus, the observed abundance and redshift distribution of clusters can set strong constraints on the underlying cosmology (Figure 6).

Figure 5: Measured n(σ) distribution for the most uniformly observed DEEP2 field (8% of the total survey). Data points indicate the number of groups in bins of 50 km/s, with error bars estimated from mock catalogs. The solid line is the mean value from mock catalogs, and the shaded region is the cosmic variance. As expected, the data are consistent with the mock catalogs for σ>400 km/s.



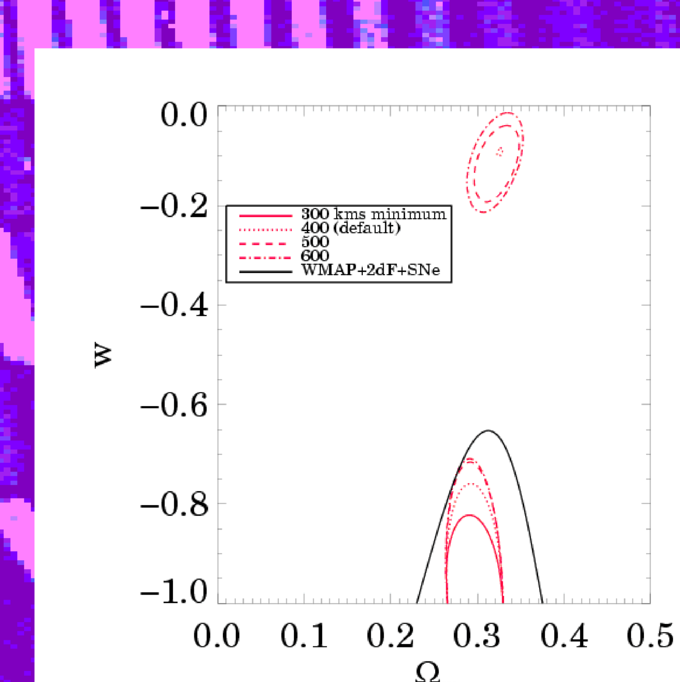


Figure 6: Predicted cosmological parameter constraints from the full DEEP2 survey. Shown are 95% confidence regions in the Ω_m-*w* plane expected from measuring the n(σ,z) distribution of a few hundred DEEP2 groups above a given threshold in σ (including statistical and systematic errors and cosmic variance). Also shown is the current constraint from WMAP + Sne + LSS

Background: Two-dimensional DEIMOS spectra, before processing